

## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

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| Applicant's or agent's file reference<br>TW200300256   | <b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416). |   |
| International Application No.<br><b>PCT/SG2003/000045</b>  | International Filing Date<br>(day/month/year)<br>7 March 2003  | Priority Date (day/month/year)<br>12 March 2002 |
| International Patent Classification (IPC) or national classification and IPC<br>Int. Cl. <sup>7</sup> G11C 11/02, 7/18, 7/20 |  |   |
| Applicant<br>AGENCY FOR SCIENCE, TECHNOLOGY AND RESEARCH et al   |  |   |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.  
☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 4 sheet(s).

3. This report contains indications relating to the following items:

- |      |                                     |   |
|------|-------------------------------------|---|
| I    | <input checked="" type="checkbox"/> | Basis of the report   |
| II   | <input type="checkbox"/>            | Priority  |
| III  | <input type="checkbox"/>            | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability  |
| IV   | <input type="checkbox"/>            | Lack of unity of invention  |
| V    | <input checked="" type="checkbox"/> | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| VI   | <input checked="" type="checkbox"/> | Certain documents cited   |
| VII  | <input type="checkbox"/>            | Certain defects in the international application  |
| VIII | <input type="checkbox"/>            | Certain observations on the international application   |

|   |   |
|---|---|
| Date of submission of the demand<br>10 October 2003   | Date of completion of the report<br>3 February 2004                               |
| Name and mailing address of the IPEA/AU<br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaustalia.gov.au<br>Facsimile No. (02) 6285 3929 | Authorized Officer<br><br><b>JYOTI SHAMDASANI</b><br>Telephone No. (02) 6283 2836 |

**I. Basis of the report****1. With regard to the elements of the international application:\***

- ☐ the international application as originally filed.
- ☒ the description, pages 1 - 9 , as originally filed,  
pages , filed with the demand,  
pages , received on with the letter of
- ☒ the claims, pages , as originally filed,  
pages , as amended (together with any statement) under Article 19,  
pages , filed with the demand,  
pages 10-13 , received on 29 January 2004 with the letter of 15 January 2004
- ☒ the drawings, pages 1/6 - 6/6, as originally filed,  
pages , filed with the demand,  
pages , received on with the letter of
- ☐ the sequence listing part of the description:  
pages , as originally filed  
pages , filed with the demand  
pages , received on with the letter of

**2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.**

These elements were available or furnished to this Authority in the following language which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

**3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:**

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

**4. ☐ The amendments have resulted in the cancellation of:**

- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/fig.

**5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).\*\***

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SG2003/000045

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

|                               |             |     |
|-------------------------------|-------------|-----|
| Novelty (N)                   | Claims 1-26 | YES |
|                               | Claims      | NO  |
| Inventive step (IS)           | Claims 1-26 | YES |
|                               | Claims      | NO  |
| Industrial applicability (IA) | Claims 1-26 | YES |
|                               | Claims      | NO  |

**2. Citations and explanations (Rule 70.7)**

US 2001/0038548

The citation though found to be a relevant art, does not disclose the particular combination of features as disclosed in the amended claims 1-26.

Claimed invention is, therefore, found to be novel and inventive.

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SG2003/000045

**VI. Certain documents cited****1. Certain published documents (Rule 70.10)**

|     | Application No.<br>Patent No. | Publication date<br>(day/month/year) | Filing date<br>(day/month/year) | Priority date ( valid claim)<br>(day/month/year) |
|-----|-------------------------------|--------------------------------------|---------------------------------|--|
| P,X | US 2002/0089874               | 11 July 2002                         | 11 January 2001                 | 11 January 2001                                  |
| P,X | US 6 385 082                  | 7 May 2002                           | 8 November 2000                 | 8 November 2000                                  |
| P,X | JP 2002 208680                | 26 July 2002                         | 11 January 2001                 | 11 January 2001                                  |
| P,X | JP 2002 208681                | 26 July 2002                         | 11 January 2001                 | 11 January 2001                                  |

*The above documents were published after the earliest priority date of this application. The PCT rules preclude reporting on such documents under Box V. It is brought to attention for information purposes only.*

When the above citations, D2 to D4 are combined with document D1, individually or severally, as would be obvious to a person skilled in the art, all the features of the claims 1-26 are disclosed.

**2. Non-written disclosures (Rule 70.9)**

| Kind of non-written disclosure | Date of non-written disclosure<br>(day/month/year) | Date of written disclosure referring to<br>non-written disclosure<br>(day/month/year) |
|--------------------------------|--|---|
|--------------------------------|--|---|

CLAIMS:

1. A multistate magnetoresistive random access memory (MRAM) unit comprising:

5 a substrate,  
a plurality of memory cells formed on said substrate,  
a bit line and a word line in electrical contact with said plurality of memory cells,

each of said plurality of memory cells including a first magnetic layer, a  
10 second magnetic layer and a non-magnetic space layer,

wherein a heat element adjacent an individual cell in said plurality of memory cells heats said first magnetic layer of said cell to near its Curie point independently of other cells, and

the magnetization vector of said first magnetic layer is aligned with a  
15 magnetic field generated by a current applied to the bit line and word line.

2. The multistate magnetoresistive random access memory unit of claim 1 wherein said first magnetic layer has a first Curie point and said second magnetic layer has a second Curie point that is higher than the first Curie point.

3. The multistate magnetoresistive random access memory unit of claim 2  
20 wherein, said first magnetic layer is a recording layer.

4. The multistate magnetoresistive random access memory unit of claim 2 wherein, said second magnetic layer is a read layer.

5. The multistate magnetoresistive random access memory unit of claim 2, wherein, said second magnetic layer is a soft magnetic layer.

25 6. The multistate magnetoresistive random access memory unit of claim 2 wherein the direction of the magnetization vector in said second magnetic layer is changed to an anti-parallel alignment with its initial magnetization vector by the magnetic field generated by the current in the word line during a read operation.

7. The multistate magnetoresistive random access memory unit of claim 2  
30 wherein, the magnetization vector in said first magnetic layer can be aligned at a plurality of angles relative to the magnetization vector of said second magnetic

layer.

8. The multistate magnetoresistive random access memory unit of claim 7 wherein the angle between the magnetization vectors of said first and second magnetic layers for an N state per cell MRAM, for the ith state,  $i=0$  to  $N-1$ , is represented by the equation:

$$\arccos(1-[2^i/(N-1)]).$$

9. The multistate magnetoresistive random access memory unit of claim 8 wherein in a four-state MRAM, the angles between the magnetization vectors of said first and second magnetic layers representing each state are,  $\arccos(1)$ ,  $\arccos(1/3)$ ,  $\arccos(-1/3)$  and  $\arccos(-1)$ .

10. The multistate magnetoresistive random access memory unit of claim 7 wherein the magnetoresistance of said plurality of memory cells is dependent upon the angles between the magnetization vectors of said first and second magnetic layers.

11. The multistate magnetoresistive random access memory unit of claim 1 wherein the plurality of memory cells are coupled into an array with each cell being individually addressable.

12. The multistate magnetoresistive random access memory unit of claim 11 wherein, said plurality of memory cells is a plurality of stacked cells including a magnetic tunnel junction cell (MTJ), or a spin-valve cell (SV) or a pseudo spin-valve (PSV) cell.

13. The multistate magnetoresistive random access memory unit of claim 12 wherein the non-magnetic space layer is a non-magnetic conductive layer in a SV cell and an insulator tunnelling layer in a MTJ cell.

14. A method of writing data in a magnetoresistive random access memory (MRAM) unit comprising a plurality of memory cells, a bit line and a word line in electrical contact with said plurality of memory cells, a heat element adjacent an individual cell in said plurality of memory cells, the method including the steps of:

raising the temperature of a first magnetic layer in said individual cell to near its Curie point independently of other cells, thereby reducing the coercivity of said layer;

writing a magnetization state in said first magnetic layer of said individual cell by passing a current through said bit line and said word line,

the current in said bit line and said word line acting cooperatively to align the magnetization vector in said first magnetic layer with a magnetic field generated by said current.

15. The method of claim 14 wherein the step of raising the temperature of said first magnetic layer is provided by applying an initial current through said individual cell.

16. The method of claim 15 wherein the initial current is applied to said heat element to heat said individual cell independently of other cells in said plurality of memory cells.

17. The method of claim 14 wherein, said plurality of memory cells is a plurality of stacked cells including a magnetic tunnel junction cell (MTJ), or a spin-valve cell (SV) or a pseudo spin-valve (PSV) cell.

18. The method of claim 17 wherein for MTJ memory cells, the heat element is a non-linear element.

19. The method of claim 18 wherein the nonlinear element is provided by a Zener diode in a reversed biased state during writing, connected to the junction of said MTJ memory cells in series.

20. The method of claim 18 wherein said Zener diode acts as a cell selector when in the reverse biased state.

21. A method of performing a read operation in a magnetoresistive random access memory (MRAM) unit comprising a plurality of memory cells, a bit line and a word line in electrical contact with said plurality of memory cells, a heat element adjacent an individual cell in said plurality of memory cells, the method including the steps of:

applying a current through said bit line,

determining the magnetization state of said first magnetic layer, wherein the resistance states of said first magnetic layer is dependent on the relative angles between the magnetization vectors of said first and second magnetic layers,

said resistance states representing the magnetization states of the MRAM,  
and

reading data represented by said magnetization states stored in said  
memory cells.

- 5 22. The method of claim 21 wherein the resistance for an N state per cell  
MRAM, for the ith state,  $i=0$  to  $N-1$ , is represented by the equation:

$$R_0 + \Delta R(i/(N-1))$$

- 10 23. The method of claim 21 wherein the direction of the magnetization vector in  
a second magnetic layer is changed to an anti-parallel alignment with its initial  
magnetization vector by a magnetic field generated by the current through said  
word line.

24. The method of claim 21 wherein the first magnetic layer is a recording layer  
and the second magnetic layer is a read layer.

- 15 25. The method of claim 19 wherein for a spin valve (SV) MRAM, the current is  
applied through said bit line.

26. The method of claim 19 wherein for a magnetic tunnel junction cell (MTJ),  
the current is applied through said bit line and word line.

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